

# PATENT SPECIFICATION

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## (54) SURGICAL INSTRUMENT HAVING SELF-REGULATING RADIANT HEATING OF ITS CUTTING EDGE

(71) I, ROBERT F. SHAW, 135 Willowbrook Drive, Portola Valley, California 94025, a citizen of the United States of America, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

10 The invention is concerned with a surgical cutting instrument having self-regulated radiant heating of its cutting edge and with a method of using it; the invention is related to those disclosed in the complete specifications of my co-pending U.K. patent application Nos. 7694/76, 7695/76, 7697/76, 15

7698/76 and 7699/76 (Serial Nos. 1,546,623, 1,546,624, 1,546,626, 1,546,627, 1,546,628).

20 The control of bleeding during surgery accounts for a major portion of the total time involved in an operation. The bleeding that occurs from the plethora of small blood vessels that pervade all tissues whenever tissues are incised obscures the surgeon's vision, reduces his precision, and often dictates slow and elaborate procedures in surgical operations. It is well known to heat the tissues to minimize bleeding from incisions, and surgical scalpels which are designed to elevate tissue temperatures and minimize bleeding are also well 25 known. One such scalpel transmits high frequency, high energy sparks from a small electrode held in the surgeon's hand to the tissues, where they are converted to heat. Typically, substantial electrical currents pass through the patient's body to a large electrode beneath the patient, which completes the electrical circuit. Discharge of sparks and temperature conversion in the tissue are poorly controlled in distribution and intensity, and erratic muscular contractions in the patient are produced so that this apparatus cannot be used to perform precise surgery. Further, apparatus of this type frequently produce severe tissue damage and debris in the form of charred and dead tissue, which materially interfere with wound 30 35 40 45

healing.

Another well-known surgical scalpel em-

5 ploys a blade with a resistive heating element which cuts the tissue and provides simultaneous hemostasis. Although these resistive elements can be readily brought to a suitably high and constant temperature in air prior to contacting tissues, as soon as portions of the blade come in contact with tissues, they are rapidly cooled. During surgery, non-predictable and continuously varying portions of the blade contact the tissues as they are being cut. As the blade cools, the tissue cutting and hemostasis become markedly less effective and tissue tends to adhere to the blade. If additional power is applied by conventional means to counteract this cooling, this additional power is dissipated to the uncooled portions of the blade, frequently resulting in excessive temperatures which may result in tissue damage and blade destruction. This results from the fact that in certain known resistively heated scalpels, the heating is a function of the current squared times the resistance ( $I^2R$ ). In conventional metallic blades of this type, the higher the temperature of any blade portion, the greater its electrical resistance, and consequently the greater the heating resulting from the power input.

55 60 65 70 75 80 85 90

It is generally recognized that to seal tissues and effect hemostasis it is desirable to operate at a temperature between 300° C. and 1000° C. And for reasons noted above, it is desirable that electrothermal hemostatic surgical cutting instruments include a mechanism by which power is selectively delivered to those portions of the cutting edge that are cooled by tissue contact so that the blade may be maintained at a substantially uniform operating temperature within the desired optimal range. Recently, hemostatic scalpels have been described (see, for example, U.S. Patent Specifications Nos. 3,768,482 and 3,826,263) in which the temperature-controlling mechanisms include resistive heating elements disposed on the surface of the scalpel blade. However, such instruments require precision in fabricating the dimensions of the heating elements to obtain the desired

resistances. And such resistive heating elements may be subjected to variations in resistance during use, as tissue juices and proteins become deposited upon the surface of the blade.

The present invention provides a cutting instrument comprising a blade having a cutting edge and an aperture remote from the cutting edge for introducing electromagnetic radiation into the blade, the blade being substantially transparent to the electromagnetic radiation between the aperture and the cutting edge, and electromagnetic radiation absorbing means disposed solely adjacent said cutting edge for heating the cutting edge.

The preferred embodiment of the present invention provides a surgical cutting instrument in which the cutting portion of the blade is brought to an elevated temperature by heating of the blade by thermal radiation. Radiant energy from a source such as a high temperature filament or ribbon or a laser is optically coupled to a substantially transparent blade an edge on which has been sharpened to form the cutting edge of the instrument. A non-radiation-transmitting internally-reflecting surface prevents loss of radiant energy from within the blade. The resultant scattering of light by internal reflections tends to distribute radiant energy throughout the interior of blade, and the optical scattering may be further enhanced by the incorporation of particulate scattering elements within the blade material.

Beneath the internally-reflecting coating and only adjacent the cutting edge of the blade, there is disposed a radiation-absorbing material which absorbs and converts the radiant energy to heat which is conducted through the material to the cutting edge to bring it to operating temperatures. The average temperature along the cutting edge may be adjusted by adjusting the power supplied by the radiation source, for example, by adjusting the electrical signals applied thereto.

Heating of those portions of the cutting edge that are cooled by tissue contact in order to maintain cutting temperatures sufficiently constant (i.e., temperature self-regulation) may be accomplished by fabricating the radiation absorber adjacent the cutting edge from a material which substantially increases in radiation absorption coefficient with decreasing temperature within the operating temperature range. Since each local region of the material absorbs the distributed radiation in accordance with its local absorption coefficient, each local region may have its temperature regulated independently of the operating temperature of adjacent regions. Thus, even in the presence of unpredictable and substantial variations in the cooling of the various regions of the heated edge resulting from the edge being manipulated to cut tissues, all regions along the length of the

cutting edge can be maintained within a suitably constant temperature range. Known thermochromic materials which have absorption coefficients that vary as a function of temperature may be used as the radiation-absorbing material in the surgical instrument of the present invention.

In the accompanying drawings:—

Figure 1 is a partial side view of a surgical cutting instrument according to one embodiment of the present invention;

Figure 2 is an end view along the line 2—2 of the instrument of Figure 1 showing the blade and the radiation source therein;

Figure 3 is a partial side view of an alternative embodiment of the present invention;

Figure 4 is an end view along the line 4—4 of the instrument of Figure 3 showing the optical channels therein for distributing radiation from a remote source; and

Figure 5 is a partial side view of another embodiment which employs segmented thermochromic regions.

Referring now to Figure 1, there is shown a partial side view of a surgical cutting instrument which has a blade 9 that is suitably attached to handle 11. A high-intensity light or thermal radiation source within the handle 11 includes a lineally-mounted incandescent filament 13 that is disposed within a parabolic reflector 15 which is oriented to direct the radiant energy from the filament toward the cutting edge 17 and facets 16 at a lower portion 18 of the blade. The lineally-mounted filament 13 assures adequate distribution of the radiant energy therefrom substantially over the length of the cutting edge 17 of blade 9. The electrical power to heat the filament 13 is applied thereto by A.C. or D.C. source 20 via conductors 21 and 22. A photodetector 30 is optically coupled to the interior of the blade 9 and is electrically connected to the power source 20 through a conventional servo-regulator 31 in a manner which controls the average power applied to the filament 13 in response to amount of radiant flux detected by photodetector 30.

Referring now to Figure 2, there is shown a cross section of the apparatus of Figure 1 including the filament 13 and the reflector 15 that directs radiant flux 5 substantially toward the facets 16 and cutting edge 17 of the blade 9. The filament 13, parabolic reflector 15 and radiation-transmitting window 14 may be formed into a chamber which is evacuated or filled with inert gas to minimize oxidation of the incandescent filament 13. The interior material of blade 9 should transmit and scatter well the radiant energy at the wavelengths of the flux 5 from filament 13 but should absorb poorly or not at all at these wavelengths. A reflective optical coating 8 is disposed over the parabolic reflector and over the internal surfaces of the blade 130

5 side walls 6 and 7 and the facets 16 of  
10 blade 9, but not over the window 14 through  
15 which the flux from the filament 13 is coupled  
20 to the blade 9. A layer 10 of radiation-  
25 absorbing, thermochromic material is disposed  
30 at the facets 16 of blade 9 adjacent the  
35 reflective coating 8 and acts as a collector of  
40 the radiant flux 5 from filament 13. The  
45 radiant flux 5 collected in layer 10 is con-  
50 verted to heat which is conducted to the  
55 cutting edge 17.

60 Thermochromic materials which have  
65 radiation absorption coefficients that vary as  
70 a function of temperature may be used as  
75 the radiation-absorbing material of layer 10.  
80 Materials which exhibit thermochromic prop-  
85 erties in selected temperature ranges include  
90 indium antimonide, gallium antimonide, and  
95 other semiconductors, zinc oxide, some lead  
100 salts, some organic and other inorganic  
105 materials.

110 Only a portion of the radiation which illu-  
115 minates the absorbing material of layer 10  
120 is absorbed. The remaining non-absorbed  
125 portion of the radiation is transmitted through  
130 the layer 10 and is internally reflected by  
135 the reflective coating 8 back through the layer  
140 10 (where further absorption occurs) and  
145 re-emerges in the substantially transparent  
150 interior region of the blade 9 which is remote  
155 from the cutting edge where it follows a  
160 multi-reflective path. As the temperature of  
165 the absorbing material 10 and hence of the  
170 cutting edge 17 increases, absorption by the  
175 material of layer 10 decreases and the average  
180 radiant flux in the transparent region of the  
185 blade 9 increases. Conversely, as the heated  
190 regions of the cutting edge 17 cool upon  
195 contact with tissue being cut, radiation absorp-  
200 tion by the material of layer 10 increases and  
205 the average radiant flux in the transparent  
210 region 9 of the blade 9 decreases. The photo-  
215 detector 30 may be coupled to the interior  
220 of the blade for monitoring the average radiant  
225 flux within the blade to increase or decrease  
230 the power supplied by the source 20 to the  
235 filament 13 as required.

240 Absorption by layer 10 of the wavelengths  
245 of radiant energy produced by filament 13  
250 thus experiences increments for temperature  
255 decrements within the operating range of the  
260 cutting edge, from 300° C. to 1000° C. It  
265 is this radiation absorption property of the  
270 material of layer 10 that provides the self-  
275 regulating means by which local regions of the  
280 cutting edge 17 that cool upon contact with  
285 tissue being cut are radiantly heated at an  
290 increased rate by increased absorption of  
295 radiation. Other local regions of the cutting  
300 edge not cooled upon contact with tissue  
305 being cut do not exhibit increased absorption  
310 and therefore do not substantially change in  
315 their conversion of radiant energy into heat.  
320 Thus, as the temperature varies in various  
325 regions of facets 16 and the layer 10 disposed

330 thereon, the radiation absorption of these  
335 regions vary inversely to assure increased  
340 radiation absorption of the cooled regions  
345 sufficient to maintain the operating tempera-  
350 ture thereof within the desired operating  
355 range.

360 As the layer 10 and cutting edge 17 heat  
365 up prior to cutting, the layer 10 becomes  
370 less absorptive and greater amounts of radiant  
375 flux 5 are reflected from layer 10 or are  
380 transmitted through layer 10 to be internally  
385 reflected by the reflective coating 8. This  
390 increases the radiation flux within the material  
395 such as glass or quartz, of blade 9. Radiation  
400 scattering centers such as rutile fibers, quartz  
405 particles, may be dispersed through the trans-  
410 parent region of the blade 9. The increased  
415 radiation flux in the transparent region of the  
420 blade 9 is detected by photodetector 30 which  
425 is connected through a conventional servo-  
430 regulator 31 to the power source 20 to  
435 decrease the power supplied to filament 13.  
440 The temperature of layer 10 and cutting edge  
445 17 and facets 16 is thus stabilized within a  
450 preselected operating range. Conversely, as  
455 portions of the cutting edge 17 and facets 16  
460 are cooled upon contact with tissue being cut,  
465 the material of layer 10 in the locally-cooled  
470 regions increases the absorption of radiant  
475 flux and decreases the level of flux in the  
480 portion of blade 9 sensed by detector 30,  
485 and this acts through servo-regulator 31 to  
490 increase the power supplied by power source  
495 20 to the filament 13. Where it is desirable  
500 to maintain a relatively uniform wavelength  
505 spectrum of radiant energy over the range of  
510 power dissipation of the cutting instrument,  
515 the amount of surface area of the filament 13  
520 heated to a specified temperature may be  
525 varied, by retracting into the handle, or rotat-  
530 ing within an aperture to vary the amount of  
535 radiant flux, rather than varying the tempera-  
540 ture of the filament operating with a  
545 fixed, exposed area.

550 Alternatively, a relatively fixed spectrum  
555 can be accomplished by utilizing a filter be-  
560 tween window 14 and the blade. Such a  
565 filter may also be used to narrow the band-  
570 width of the radiant energy, and thereby  
575 simplify the selection of absorbing materials  
580 used in layer 10 or, the filament 13 may be  
585 replaced by the ionized gas column of a gas  
590 discharge tube which emits radiant energy  
595 within one or a few characteristically narrow  
600 spectral lines, and which thus also simplifies  
605 the selection of absorbing materials used in  
610 layer 10.

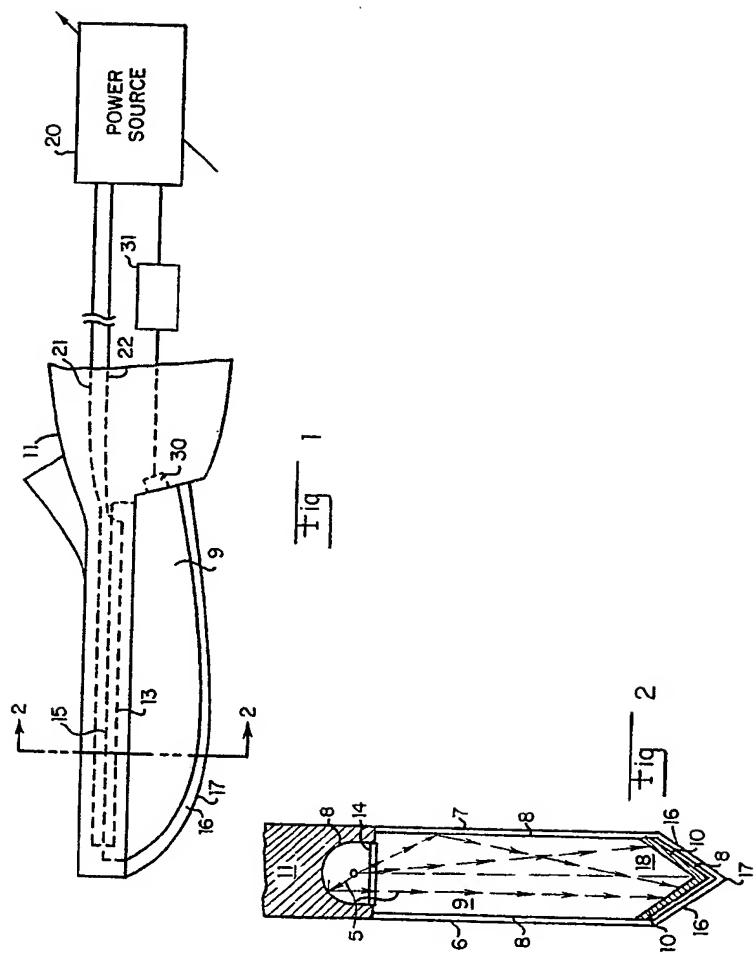
615 Referring now to Figures 3 and 4, there  
620 are shown side and end views, respectively,  
625 of an alternative embodiment of the present  
630 invention in which the radiant source is dis-  
635 posed remotely from the cutting instrument.  
640 Fiber optic filaments are aligned in a linear  
645 array 33 to irradiate the absorbing layer 10.  
650 A photodetector 30 may be disposed within

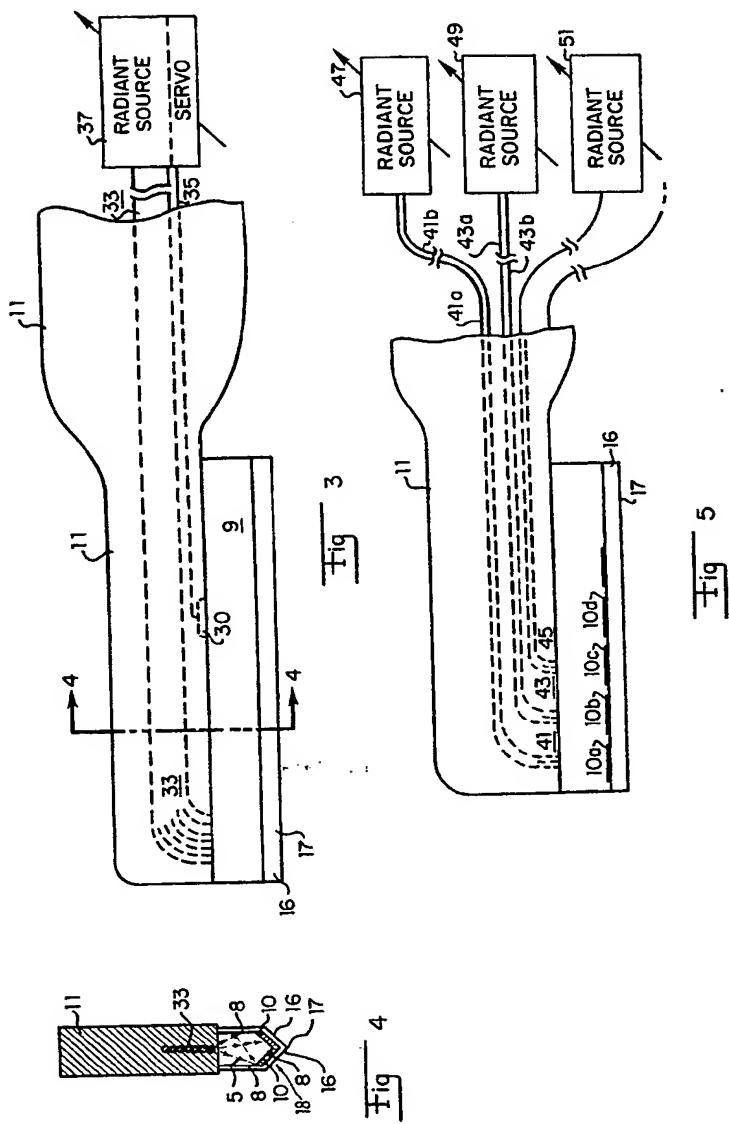
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|----|---|-----|
| 5  | the handle 11 to detect the level of radiant flux and to produce a control signal on line 35 in response thereto for controlling the power output from the remote source 37, such as a laser. Alternatively, selected fibers in the array 33 can be used to sample radiant flux at locations along the length of the blade and illuminate a photodetector, thereby to produce the requisite power-controlling signal.   | 60  |
| 10 | Also, other optical means such as reflective mirrors and lenses may be used instead of the optical fibers to direct the radiant energy from the remote source into the absorbing layer 10.  | 65  |
| 15 | Figure 5 illustrates still another embodiment of the present invention in which the material of the absorbing layers 10a, 10b, 10c, etc. exhibits relatively constant absorption characteristic for converting radiant energy into heat for heating cutting edge 17 and also serves as an infrared radiation source whose radiation spectrum is a measure of its temperature. The illuminating 41a, 43a, etc. and detecting 41b, 43b, etc. fibers going to and coming from short discrete segments of the absorbing layer 10a, 10b, 10c, etc. can be gathered into two separate bundles for each segment. By utilizing a separate radiant source 47, 49, 51, etc. to illuminate the radiation absorbing material of each segment 10a, 10b, 10c, etc. and a separate detector for each source associated with each detecting fiber 41b, 43b, etc., the temperature of each segment can be independently monitored and the power output of the corresponding radiant source can be independently regulated so that the temperature of each segment along the cutting edge 17 can be maintained within a suitably constant temperature range, independent of the other segments along the cutting edge. Utilizing this principle, a rapidly-responding radiant source and detector may be time-shared among several segments along the length of the cutting edge 17. Further, a plurality of individual filaments of the type previously described with reference to Figures 1 and 2 may be linearly positioned along the length of the cutting edge 17 in order to independently elevate and regulate the temperature of a corresponding segment, independently of the temperature of an adjacent segment. | 70  |
| 20 |   | 75  |
| 25 |   | 80  |
| 30 |   | 85  |
| 35 |   | 90  |
| 40 |   | 95  |
| 45 |   | 100 |
| 50 |   | 105 |
| 55 | WHAT I CLAIM IS:—<br>1. A cutting instrument comprising a blade having a cutting edge and an aperture remote from the cutting edge for introducing electromagnetic radiation into the blade, the blade being substantially transparent to the electromagnetic radiation between the aperture and the cutting edge and electromagnetic radiation absorbing means disposed solely adjacent said cutting edge for heating the cutting edge.  | 110 |
|    | 2. A cutting instrument according to claim 1, wherein radiation reflecting means is disposed on surfaces of the blade to contain radiant energy therein.  | 115 |
|    | 3. A cutting instrument according to claim 1, wherein the radiation absorbing means exhibits increased absorption in response to decrease in temperature over a portion of the temperature range from 300° C. to 1000° C.   |     |
|    | 4. A cutting instrument according to claim 1, wherein the radiation absorbing means exhibits increased reflectance of radiation for increased temperature over a portion of the temperature range from 300° C. to 1000° C.  |     |
|    | 5. A cutting instrument according to claim 1, wherein the radiation absorbing means exhibits increased transmission of radiation for increased temperature over a portion of the temperature range from 300° C. to 1000° C.   |     |
|    | 6. A cutting instrument according to claim 1, wherein radiation scattering means is provided within the transparent portion of the blade.   |     |
|    | 7. A cutting instrument according to any one of the preceding claims, wherein a source of electromagnetic radiation is coupled through the aperture to irradiate the radiation absorbing means.   |     |
|    | 8. A cutting instrument according to claim 7, wherein the source of radiation includes an incandescent filament.  |     |
|    | 9. A cutting instrument according to claim 7, wherein the source includes a gas-discharge source.   |     |
|    | 10. A cutting instrument according to claim 9, wherein the gas-discharge source includes a laser.   |     |
|    | 11. A cutting instrument according to claim 7, wherein the source of radiation is connected to the aperture by reflecting means.  |     |
|    | 12. A cutting instrument according to claim 7, wherein the source of radiation is connected to the aperture by optical fibers.  |     |
|    | 13. A cutting instrument according to any of the preceding claims, wherein photoresponsive means is disposed to produce a control signal in response to the amount of radiation within the blade.   |     |
|    | 14. A cutting instrument according to claim 13, wherein the source of radiation can receive the control signal for altering the level of radiation produced by the source to maintain the average temperature of the radiation absorbing means within a selected operating temperature range.   |     |

15. A cutting instrument substantially as hereinbefore described with reference to the accompanying drawings.

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